“Attention Training and Its Effect on Cognitive Workload Using Physiological Signal”

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1) Introduction: -

Academic performance not only depends on the amount of time spend in the study and understanding of a learning material but also depends on the cognitive and psychological factors of an individual. The cognitive load depends on the amount of mental workload in performing a task. In the case of a text reading task, one continuously moves the eye gaze along the text with intermittent and momentary fixations, during this time various parts of the brain namely occipital, temporal and frontal lobes get activated in a particular sequence. In order to obtain an optimum performance, an individual needs to be in a "flow" state. …This is achieved by maintaining a balance between the challenge in a task and the skill of an individual. Hence is the need for adaptation of the task based on the cognitive and psychological state of an individual, leading to the personalization of the learning processing order to do so, it is important to categorize tasks or educational contents based on cognitive load, as well as understand the individual traits.

Far Eastern cultures, attention training has long been used for the developing of ''well-being,'' and its gradual disassociation from religious practice has allowed it to be subjected to scientific inquiry. Of late, attention training has been widely adopted especially in the West and is increasingly being used worldwide for the alleviation of stress and for the treatment of common psychiatric disorders, such as depression and anxiety. The seemingly powerful effects of attention training are intriguing, and the potential health benefits have aroused particular interest, as individuals search for alternatives modern-day medicines. Since the 1970s, a majority of studies have focused on concentrative attention training techniques and transcendental meditation.

Over the past decade, however, there has been a shift toward various types of mindfulness meditation and nondirective meditation, as these techniques have increasingly been embraced by psychologists and psychiatrists. This is evidenced by their integration with psychotherapeutic techniques for the treatment of medical and psycho logic problems. Although recent studies have demonstrated the effectiveness of such interventions, understanding of how attention training exerts its biological effects remains rudimentary. Its neural basis has been investigated using electroencephalography (EEG), and these studies have provided some insight into the neurophysiology of meditation, including long-term changes in cortical activity.5,6 An emerging body of literature suggests that attention training

activates regions of the brain involved in the monitoring and regulation of emotion, attention, and autonomic body functions.

Several studies have reported increased EEG theta and alpha activity, along with increased bilateral alpha coherence in experienced mediators. For several decades, electroencephalographic (EEG) recordings have been used for the study of cognitive functions. These oscillations have been classified by their frequency since the very early papers after the discovery of EEG by Berger (Adrian and Mathews, 1934).

The technological development of digital EEG resulted in a more precise quantification of EEG frequencies and the definition of bands of frequencies that have the approximate following ranges: 0.5–3.5 Hz for delta, 4–7.5 Hz for theta, 8–12.5 Hz for alpha, 13–30Hz for beta and higher than 30Hz for gamma. A very slow activity, lower than 1 Hz oscillations, has also been considered (Steriade et al., 1993). At the moment, a large body of evidence suggests that oscillatory activity in all frequency bands is linked to a broad variety of perceptual, sensor motor, and cognitive operations (Basar, 1998; Aoki et al., 1999; Klimesch, 1999; Palva and Palva, 2007). However, in recent years, studies relating EEG oscillations with cognitive processes have focused on alpha and theta frequencies, beta and gamma frequencies and, more recently, very slow activity. Over the last 40 years, various attention training techniques have been widely accepted in Western cultures and gradually become subject of scientific scrutiny.

Since the 1970s, several studies have focused on concentrative attention training techniques and transcendental attention training (TM). Over the past decade, a shift towards various mindfulness meditations, and nondirective attention training has occurred. Beneficial health effects of attention training are often attributed to positive changes in autonomous nerve activity, manifesting as reduced heart and respiratory rates, reduced oxygen uptake, and reduced circulating plasma catecholamine levels. Several authors report changes in heart rate variability (HRV) during concentrative Zen techniques by healthy participants, characterized as reduced sympathetic and increased parasympathetic activity. The latter is known to be respiration dependent, and the effects on sympathetic versus parasympathetic nerve activity may vary among methods related to volitional versus spontaneous breathing and other characteristic s of the practice.

2) Problem Statement: -

To design robust system used to measure the cognitive load quantitively for doing the arithmetic operation and logical reasoning operations.

3) Objective: -

- Quantification of cognitive load while doing arithmetic's operations using physiological signal.
- Quantification of cognitive load while doing logical reasoning operations using physiological signal.
- Analysing synchrony among various brain regions while doing arithmetic's operations & logical reasoning operations.
- Quantifying verbal cognitive load developing proper tests.

4) Literature Survey: -

The attention training practising group showed increased α, β, and δ EEG band powers and significant reduction in θ and γ band powers. The increased α and β power can represent enhanced cognitive functions such as memory and concentration, and that of δ signifies synchronization of brain activity. The heart rate index θ/α decreased, neural activity β/θ increased, attention resource index $\beta/(\alpha + \theta)$ increased, executive load index $(\delta + \theta)/\alpha$ decreased, and the ratio $(\delta + \theta)/(\alpha + \beta)$ decreased.

Attention training practising group showed significant improvement in various cognitive functions, such as performance enhancement, neural activity, attention, and executive function. It also resulted in increase in the heart rate variability parasympathetic nervous system activity, and balanced autonomic nervous system reactivity. Attention training affects many cognitive abilities. The stress and anxiety are reduced by the attention training practice. The effect of the cognitive load has been observed at the frontal and temporal lobe. The reaction time has been in-creased as load level increases. [1]

In this paper, the effect of attention training on the seven load arithmetic tasks using Electroencephalogram (EEG) is investigated. The focused attention on breathing is taught to 11 healthy subjects as a simple attention training technique. EEG signals have been recorded at the beginning of attention training and after four weeks of regular attention training(daily

20 minutes) using EMOTIV device. The higher order crossings (HOC) features are derived from EEG signals for analysis of seven cognitive loads. The pre and post-experiment results are compared based on reaction time and effect on brain lobe. The K-Nearest Neighbors (K-NN) classifier is used for classification of seven loads and achieved 83.57% accuracy in the post and 89.61 % accuracy in pre-experiment. [2]

Level	**Task**	**Example**
L1(Easy)	1- & 2-digit numbers addition	5+3
L2	1- & 2-digit numbers addition with one carry	64+6
L3	2-digit numbers addition with one carry	64+62
L4	2-digit numbers addition with two carries	77+33
L5	2- & 3-digit numbers addition with one carry	288+21
L6	2- & 3-digit numbers addition with two carries	399+34
L7 (Difficult)	3-digit numbers addition with three carry	978+895

Table 1: Analysis of effect of attention and training

In this paper he investigates the effect of attention training practice on cognitive skills, autonomic nervous system, and heart rate variability by analysing physiological parameters. The study was conducted on 30 normal young healthy engineering students. The attention training practising group showed increased α, β, and δ EEG band powers and significant reduction in θ and γ band powers. The increased α and β power can represent enhanced cognitive functions such as memory and concentration, and that of δ signifies synchronization of brain activity. Attention training practising group showed significant improvement in various cognitive functions, such as performance enhancement, neural activity, attention, and executive function. It also resulted in increase in the heart rate variability, parasympathetic nervous system activity, and balanced autonomic nervous system reactivity. [3]

It was concluded that breathing, meditation, increased overall brain wave activity. Attention training practice may be an effective adjunctive treatment for a clinical and healthy aging population. Attention training seems to have positive effects on brainwave activity in terms of stimulating the activation of alpha, beta, and theta brainwaves, which have been associated with improvements in cognition, memory, mood, and anxiety.
Attention training t has been correlated with decreased amygdala activation decreased negative emotion in response to emotional distracter images. Attention training also seems to have a constructive effect on the anatomy of the brain. The implementation of attention training into the clinical treatment of certain neurological and psychosocial disorders may be beneficial to these populations because of its neuroplastic effects.[4]

In this paper he observed that Quantification of the level of cognitive load experienced during reading a textual content, by a group of participants, helps in analyzing the overall content. Detailed and localized analysis of a content, based on an individual response, is also useful to understand individual traits in silent reading as well as to improve the content. Affordable sensors namely, EEG and pupillary responses are used to perform both global and detailed quantification. Easy and difficult textual paragraphs are used for the experiment. The entropy of the line-wise cognitive load derived from the left temporal lobe is capable of detecting the overall difference between the two types of contents. The Eigenvalue analysis of the oscillatory nature of the pupil dilation gives insights into the difficult phrases in a text. This is used to analyze individual specific performance in the reading task. In future we aim to derive features from the limit cycles of the pupil response and perform a causal analysis with the EEG signals in an unsupervised manner. [5]

In this paper he observed that power spectral density of the Alpha band for mentioned brain regions were extracted. Each brain region is associated with different cognitive activity. In 2D multimedia animations learning based cognitive task, we have examined a clear Alpha PSD de-synchronization on frontal, temporal, parietal and occipital brain regions. As the occipital and parietal regions are associated with visual information interpretation and processing, there is a high Alpha power de-synchronization is observed as compare to frontal and temporal regions. These findings show, more cognitive load had been imposed by the working memory on parietal and occipital regions. Later in future, these finding can be used to investigate that how 2D multimedia animations effect the learning in educational field. [6]

5) Methodology: - (Protocols)

I have designed two different protocols to study impact of attention training on subject.

[A] There are three different tasks related to BODMAS. They are varying from low level, medium level, and difficulty level.

- Simple level (without carry)

1) 3+4 =?

2) 2+5=?

3) 3+5=?

- Medium level (with carry)

1) 4+8=?

2) 5+9=?

3) 8+9=?

- Difficulty level (apply BODMAS rule)

1) .(5+4)* 4 =?

2) (5*2) % 2=?

3) (9-3) %2*2 =?

❖ There are five different tasks related to Logical Reasoning. They are varying from low level, medium level, and difficulty level.

A) Simple level

- Display letter on screen and ask to subject which is that letter. e.g. A, B, C. & so on.

B) Medium level

- Display letter on screen & subject has to tell its location whether it is even position or odd position. e.g. A is odd; B is even & so on.

C) Difficulty level

- Display letter on screen & subject has to tell its opposite letter & its location number. e.g. display letter is A its opposite letter is Z & its location is 26.

D) Difficulty level

- Display letter on screen & subject has to tell its opposite letter & perform addition of both the letter position number e.g. if display letter is A, its opposite letter is Z & addition of both numbers is 27.

E) Most Difficulty levels

- Display letter on screen & subject has to tell its opposite letter & perform multiplication of both the letter position numbers e.g. if display letter is A, its opposite letter is Z & multiplication of both numbers is 26.

6) Future Plan: -

- Material and method: -

1) The subjects

EEG signals are will be record from 20 healthy (12 males and 08 females) institute students in the age group of 22.5 (±1.0) years participated voluntarily as the subjects in pre and post experiment. Before the experiment, the subjects have signed a consent form and have been introduced about cognitive tasks and attention training instructions. The subjects performed daily attention training of 20 minutes with spine erect and concentrate on the centre of two eyes and say om mantra for 30 second, get relax for 30 second and repeat it till 20 minutes.

2) EEG data recording

EEG signals are recorded using ENOBIO wireless EEG device on a separate recording laptop. The arithmetic tasks and logical reasoning tasks are displayed using another laptop, 60 cm away from the subject in order to minimize eye and any physical movements. The EEG recording has been done using thirty-two electrodes ENOBIO headset with sampling frequency 500 Hz. The thirty-two electrodes: AF3, AF4, F3, F4, FC5, FC6, F7, F8, T7, T8, P7, P8, O1, and O2 etc. are based on the international 10-20 EEG format. The EEG is recorded during three arithmetic task and four logical reasoning tasks levels in pre and post experiment of the same subject.

The subjects are asked to avoid any physical movements to minimize the artifacts of muscle movement. The correct answer is indicated by raising subject hand up and finger 1, 2, 3, & 4 by keeping a hand in a fixed position. The subject could make eye blinks or movements in 30 seconds' break between each two levels.

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